NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Climate Change and Renewable Energy
A Perspective from a Measurements Viewpoint

Regional Workshop on
Metrology and Technology Challenges of
Climate Change and Renewable Energy

Guatemala City, Guatemala

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James R. Whetstone

Special Assistant to the Director for Greenhouse Measurements

National Institute of Standards and Technology

Agenda

- The Importance of Greenhouse Gases in the Atmosphere
  - The trace atmospheric gases and the greenhouse effect
- U.S. Greenhouse Gas Emissions Data and Reporting
  - Emissions summaries
  - Emissions and Uptake, The Emission – Activity Factor Model
  - Reporting Protocols
- Greenhouse Gas Mitigation – International Aspects
- Renewable Energy
  - Alternatives
  - Impact of energy efficiency
  - Buildings

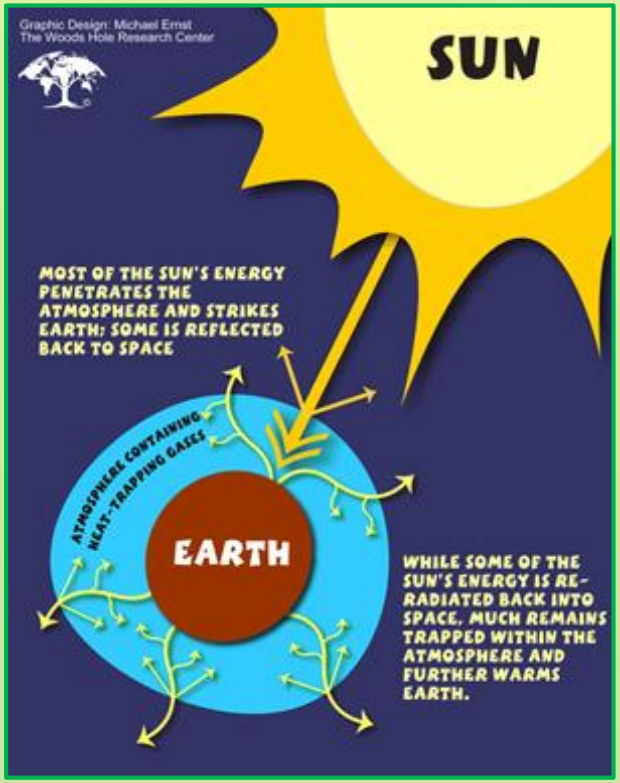
Earth's Systems are Powered by Solar Energy

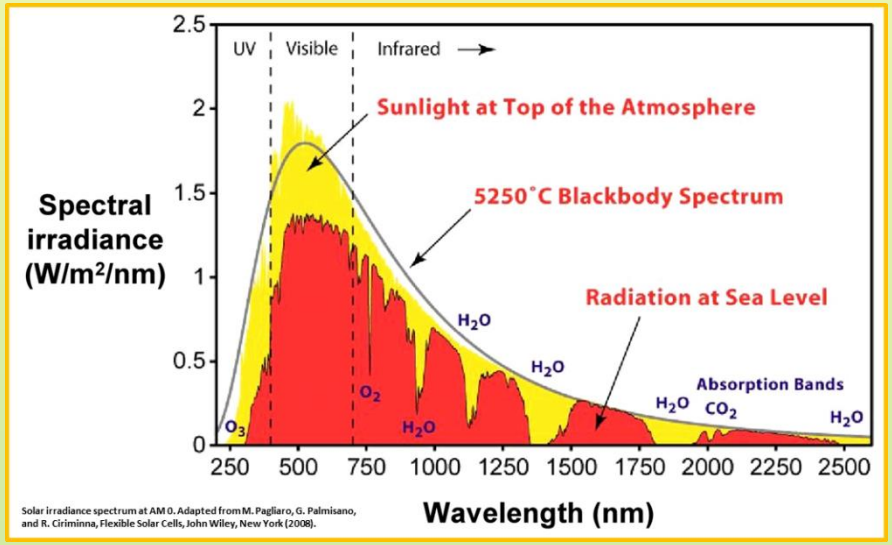
Fate & Effects of Incident Photons

Solar Energy falling on the Earth's surface undergoes numerous physical processes.

Effects on incoming solar photons:

- Reflection and scattering by clouds, particles, and molecules in the atmosphere
  - Scattered in the atmosphere & don't impact the Earth
  - Scattered & reflected by the Earth's surface through the atmosphere to space
- Energy conversion by various mechanisms at Earth's Surface
  - Photosynthesis converts photons to biochemical energy
  - Surface absorption & conversion
    - Man-Made Surfaces – roads, parking lot surfaces, buildings
    - Natural Surfaces – soils, rocks, rivers & streams, oceans





Radiative Processes & Effects

- The Sun is a high temperature radiation source emitting short wavelength radiation – visible & ultraviolet
- Components of Earth's atmosphere selectively absorb solar radiation on its way to the surface
  - Ozone (O_3) strongly absorbs UV radiation protecting plant and animal life on Earth's surface
  - The greenhouse effect:
    - maintains Earth's surface temperature near 23° C
    - driven by strong infrared absorption
    - water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halocarbons

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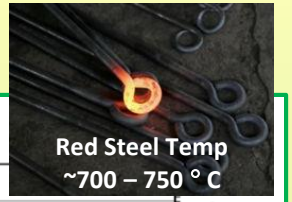
Earth's Greenhouse

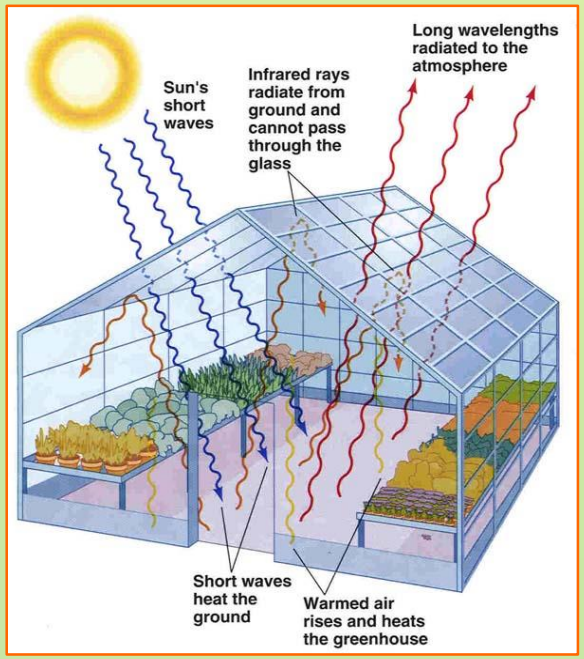
Powered Both by Solar & Terrestrial Radiation



Earth's Surfaces Emit Radiation

- Earth's surface absorbs & converts shortwave radiation, visible and near ultraviolet, to longer wave radiation in the infrared
- Thermal, or Blackbody, radiation intensity depends on surface temperatures
- ~9.7 μm radiation emitted at ~295 K (~23 °C) surface temperature

Earth's Greenhouse



Selective Absorption Warms Atmospheric Gases

- Earth's surface acts as a radiation source, emitting thermal radiation in the infrared spectral region
- Molecular gases, CO_2, CH_4, N_2O, & H_2O strongly absorb thermal radiation over the ~ 2 – 30 μm range,
- Small concentrations of these gases have large effects because their absorption strength is much larger than nitrogen and oxygen (~99% of the atmosphere)
- Molecular collisions quickly transfers absorbed thermal energy to N_2 & O_2
- Radiate back to the surface

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Impacts of Greenhouse Gases on the Earth

- **Earth's Greenhouse**
  - Driven by gases, water vapor, carbon dioxide, methane, nitrous oxide, and halocarbon compounds, in the atmosphere that:
    - strongly absorb thermal radiation emitted from Earth's surface
    - Transfer this energy to major components warming the atmosphere
  - Without this effect, the average temperature of Earth's surface could be -20° C or below and life as we know it would not exist

- **Our greenhouse operates in a relatively delicate balance between incoming solar radiation and outgoing thermal radiation**
- **Small amounts of greenhouse gases in the atmosphere strongly absorb thermal radiation, changing atmospheric temperatures by passing that energy to the atmosphere's major components, nitrogen and oxygen**

Impacts of Greenhouse Gases on the Earth

- The International Panel on Climate Change (IPCC) has developed significant scientific information on our climate and asserts that man made greenhouse gas emissions are beginning to significantly alter the balance that is the Earth's greenhouse
- Although water vapor is produced anthropogenically, the amount emitted to the atmosphere is a very small fraction relative to that emitted by the oceans.
- Carbon dioxide, methane, and nitrous oxide are emitted by human activities in the largest amounts and are the focus of:
  - Greenhouse inventory statements by nations
  - Potential mitigation efforts both nationally and internationally
- Concerns about climate changes that adversely impact Earth's population place increased emphasis on greenhouse gases produced by human activities.

GREENHOUSE GAS INVENTORIES

U.S. Greenhouse Emissions Data

Emissions Data Development Model

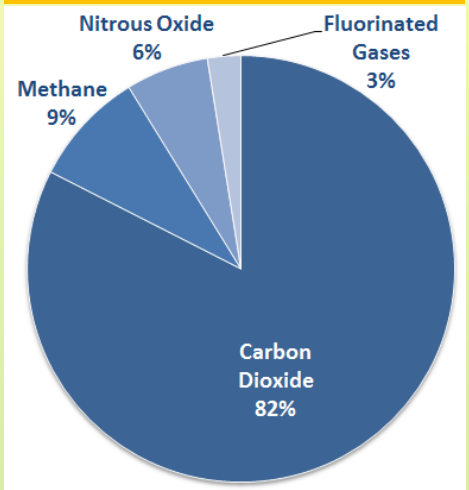
Measurements Supporting Reporting

International greenhouse gas mitigation

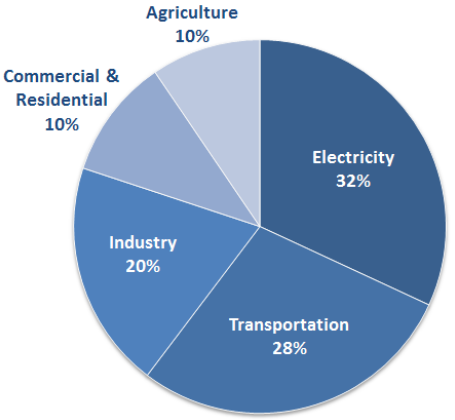
U.S. Greenhouse Gas Emissions Reporting

- **U.S. Environmental Protection Agency develops an annual report, the Inventory of U.S. Greenhouse Gas Emissions and Sinks (Inventory).**
  - Tracks total annual U.S. emissions and removals by source, economic sector, and greenhouse gas going back to 1990.
  - National energy, agricultural activities, and other national data and statistics are the means of providing a comprehensive accounting of total greenhouse gas emissions for man-made greenhouse gas sources in the United States.
- **Greenhouse Gas Reporting Program:**
  - Collects greenhouse gas emissions data from individual facilities and suppliers of certain fossil fuels and industrial gases.
- **U.S. EPA submits this report yearly to the UN in accordance with the UN Framework Convention on Climate Change (UNFCCC)**

U.S. Greenhouse Gas Emissions in 2012



Emissions by Economic Sector



Total Emissions in 2012
6,526 Million Metric Tons of CO_2 equivalent

http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

Greenhouse Gas Emissions Reporting Methodology

The Emission – Activity Factor Model

$$GHG\ Mass\ Emitted/Absorbed = EF * AF$$

EF – Emission Factor (GHG mass/unit activity)
AF – Activity Factor – amount of activity
(miles traveled – transportation systems)
(miles of pipeline – natural gas trans. & distribution)
(hectares or acres – land surface, agricultural or forest)

- **Primary conceptual method for computation of the mass of greenhouse gas either absorbed or emitted to the atmosphere from a process or an entity.**
- **Emission Factor contains the quantity of GHG of interest**
  - **Units: tons/megawatt, tons/mile traveled, tons/mile of pipeline, tons/hectare**
  - **Applicable to both emission and uptake**
  - **CO_2 uptake – a natural process, almost always a biogenic process such as the growth of forests**
- **Activity Factor counts the number engaged in the process of interest**
  - **Megawatts, miles travelled or of pipeline, area**

Greenhouse Gas Emissions Reporting Methodology

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- **Strength : A simple concept easily applied**
  - Simplicity can also raise issues in it's application to specific situations
- **Emission factors**
  - Based on some type of observational or experimental data
  - Can remain sufficiently accurate for processes where the emission/uptake mechanism is well-understood and properly characterized
  - May require period revision in cases where:
    - the emission process has changed, for example, where technological changes have changed the nature of the process
    - New measurement capabilities have improved accuracy
- **Incorporated into the UNFCCC national GHG reporting methodology**

International Climate Policy Drivers

Focus on Greenhouse Gas Mitigation Issues

The Bali Action Plan, Section 1 – UNFCCC Convention of the Parties #13, 2007

- **Recognizing that deep cuts in global emissions will be required …,**
- **Decides to launch a comprehensive process to enable the full, effective and sustained implementation of the Convention … to reach an agreed outcome and adopt a decision at its fifteenth session, by addressing, inter alia:**
  - **A shared vision for long-term cooperative action, including a long-term global goal for emission reductions, … ;**
  - **Enhanced national/international action on mitigation of climate change, including, … of:**
    - a) ***Measurable, Reportable and Verifiable (MRV) Nationally Appropriate Mitigation Commitments Or Actions (NAMAs)***, including quantified emission limitation and reduction objectives, by all developed country Parties, while ensuring the comparability of efforts among them, taking into account differences in their national circumstances;
    - b) Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner;
    - c) …

International Climate Policy Drivers

Focus on Greenhouse Gas Mitigation Issues

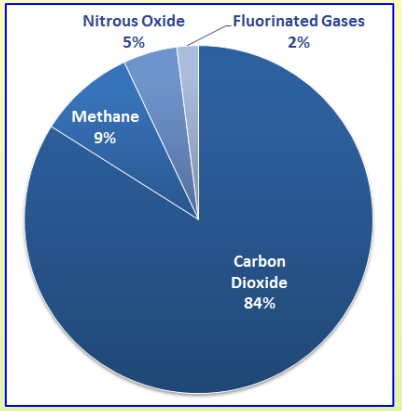
International Greenhouse Gas Mitigation Efforts based central concepts and practices that are strongly aligned with the missions of National Metrology Institutes and of the International NMI Community.

- **Consistency, Transparency, Accuracy and Comparability of GHG inventories.**
- **The Capability to Measure, Report, and Verify GHG Inventories will be keystones for their recognition internationally.**
- **Concepts in UNFCCC's Bali Action Plan, & its likely antecedents, are based on proven scientific principles fundamental to NMI standards operations – Independent Validation of Observed Values**

MRV Issues & Linkages

- **MRV – Measureable, Reportable, and Verifiable GHG inventory data**
- **A foundational *mitigation effectiveness metric***
- **MRV concepts are:**
  - **Pervasive in climate mitigation**
  - **Closely linked to renewable energy and energy security concepts**
  - **Applied to technology, finance, and capacity building concepts**
  - **Directly linked to Sustainability concepts**
  - **Verifiable methodologies should be independent of sources for scientific stringency**

What is NIST Doing in Greenhouse Gas and Climate Science Measurements



2011 U.S. Emissions
6,702 M Metric Tons CO_{2e}

Program Objectives:

- **Develop advanced measurement tools and standards:**
  - To improve the accuracy capability for:
    - Greenhouse gas inventory data, and
    - Remote observations, both satellite and surface-based

    with an emphasis on cities and metropolitan areas.
  - That independently verify greenhouse gas emissions inventories both nationally and internationally, and
  - That extend measurement science to better understand and describe the Earth's climate and its change drivers.
- **Enable international measurement standards and protocol developments that ensures accuracy, confidence, and reliability of local and global assessments of GHG emissions.**

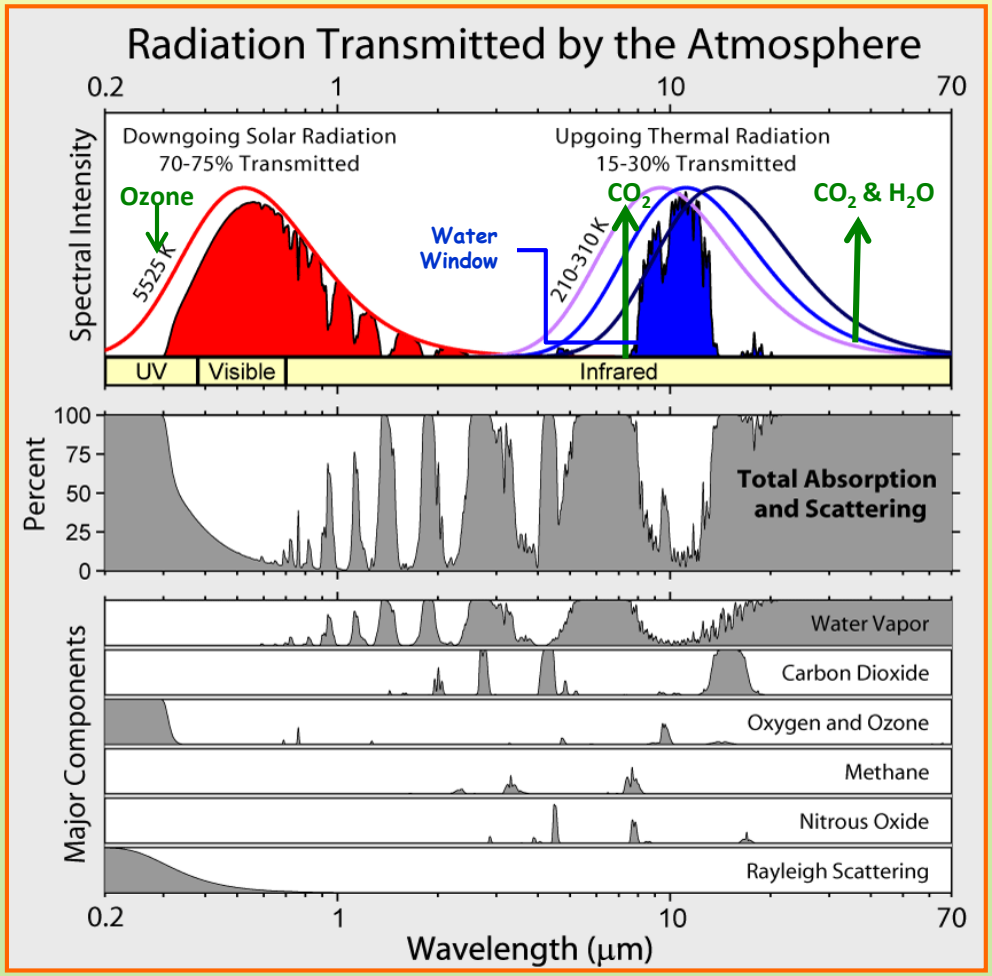
GHG Emissions Data, the basis for:
- National GHG inventories
- Basic data/information utilized by future market-based and/or regulatory-based mitigation policy mechanisms
- Primary atmospheric radiative forcing agents

Remote Observations:
- A Mainstay for Climate Observations
- Accuracy and continuity of climate data records
- Potential applications in GHG mitigation policy verification

Program Components

Greenhouse Gas and Climate Science Measurements

- **GHG Measurements Tools, Standards, and Reference Data**
  - GHG Concentration Standards
  - Spectroscopic Reference Data
  - Surface Air Temperature Assessment
- **Climate Science Measurements - Advanced Satellite Calibration Standards**
  - Optical and Microwave
  - Top of Atmosphere and Surface Solar Radiance
- **Aerosol Measurement Science**
  - Black Carbon Optical Properties
  - Black Carbon Reference Materials and Measurements
- **Stationary/Point Source Metrology**
  - Test Beds for Continuous Emission Monitoring Technologies
- **Distributed GHG Source Metrology**
  - GHG Flux Measurement Tools
    - Differential Absorption Lidar Developments
  - Measurement Approaches in Urban Settings
    - Dense GHG Observing Networks – Measurements to Independently Verify GHG Emission Inventories
    - Indianapolis Flux Experiment - INFLUX
    - Los Angeles Megacity Carbon Project
    - Extension to Megacities and Development of an International Metrology Framework for MRV



NIST EFFORTS IN SMART GRID, BUILDING ENERGY EFFICIENCY, AND PHOTOVOLTAICS

- Measurement Science Research at NIST Centered in its Engineering Laboratory
- Strong Interactions with U.S. industrial sectors concerned with manufacturing, building and construction, and infrastructure
- Standards development utilizes the rather unique U.S. consensus process and Standards Developing Organizations

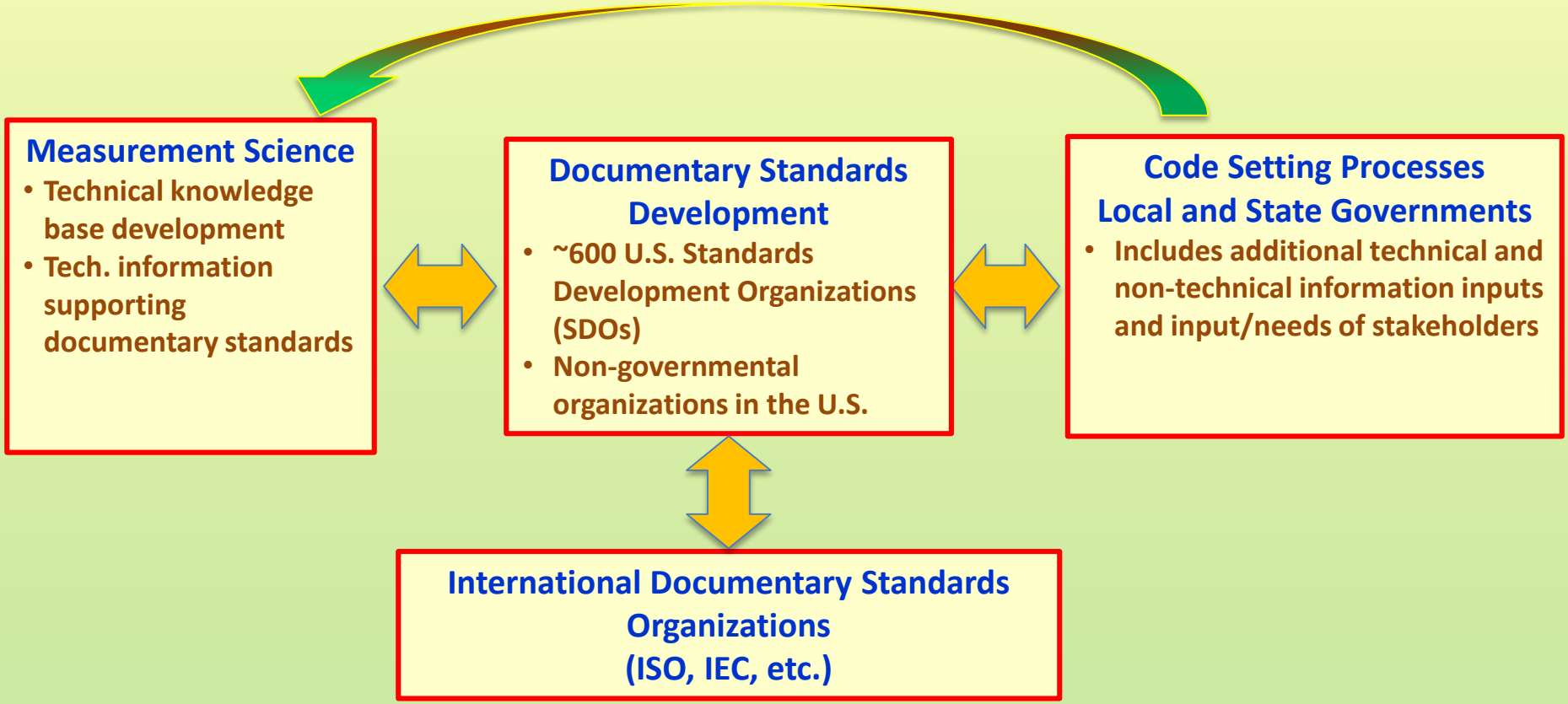
NIST Engineering Laboratory

Research Objective and Vision

- **Objective:**
  Anticipates and meets measurement science and standards needs for technology-intensive manufacturing, construction, and cyber-physical systems, including the *Smart Grid Program Office*, in ways that enhance economic prosperity and improve the quality of life.
- **Vision:**
  Be the source for:
  - **Solution-enabling measurement science , and**
  - **Technical contributions underpinning emerging standards, codes, and regulations used by the U.S. manufacturing, construction, and infrastructure industries to strengthen leadership in domestic and international markets.**

NIST Measurement Science Research

Supporting U.S. Codes & Standards



- U.S. Codes and Documentary Standards are Publically Available both Nationally and Internationally
- Building Codes are Often Regulatory in Nature Involving Public Health and Safety Issues

Smart Grid in the U.S.

https://www.smartgrid.gov/

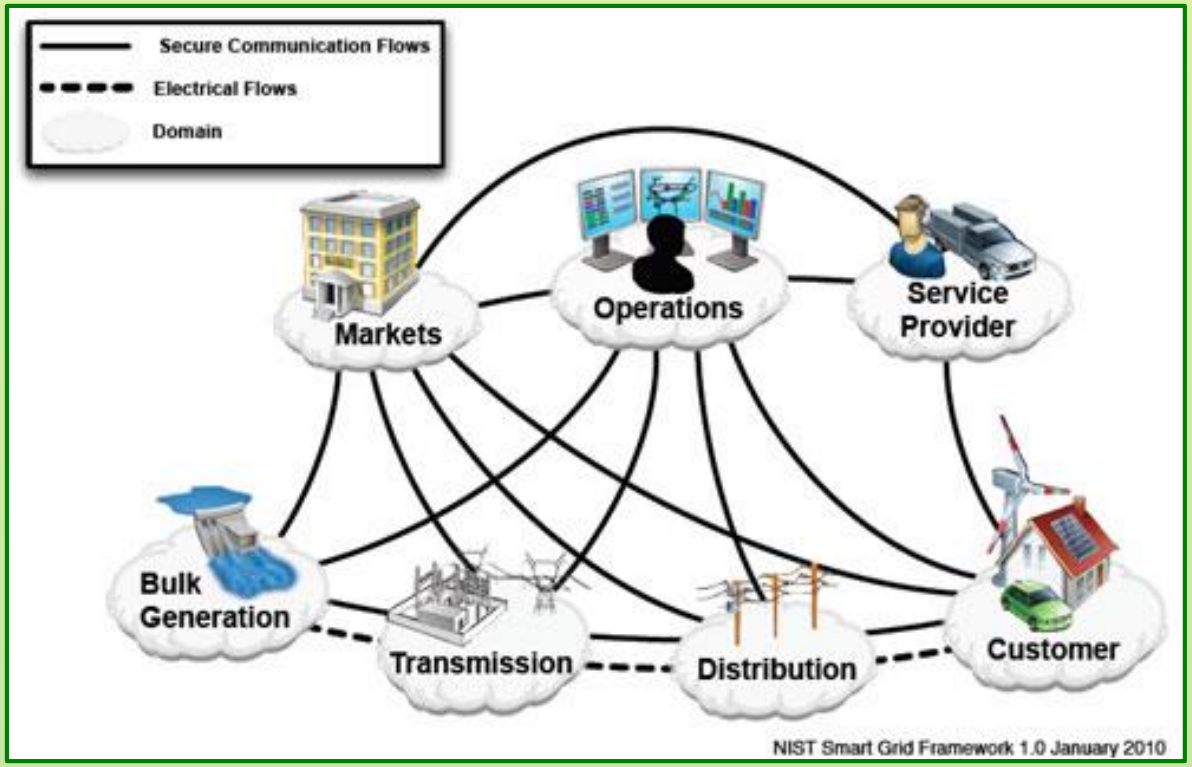
What is it?

- "Smart grid" generally refers to a class of technology that will bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation.
- The two-way communications technology and computer processing used for decades in other industries make this possible.
- Electricity networks are being transformed
  - Distributed generation is being enabled to include traditional power plants, wind and photovoltaic farms, and other renewable sources to electricity consumers via the smart grid
  - Enabling distributed generation – Some consumers are beginning to become producers.
  - Benefits to utilities and consumers – significant improvements in energy efficiency on the electricity grid and in the energy users' homes and offices.

Smart Grid in the U.S.

From a NIST Perspective

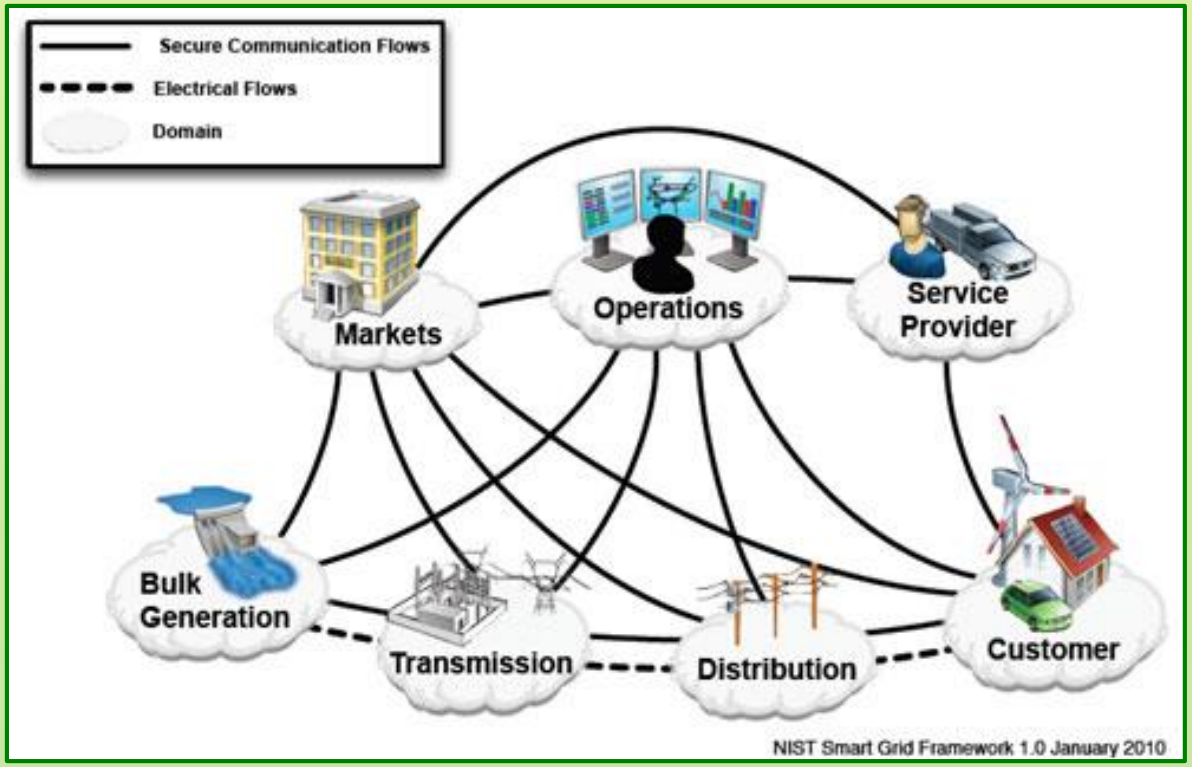
- The NIST Smart Grid Program aims to develop and deploy advances in measurement science to enable integration of interoperable and secure real-time sensing, control, communications, information and power technologies to increase efficiency, reliability and sustainability of the nation's electric grid.
- A documentary standards and measurements research effort



Smart Grid in the U.S.

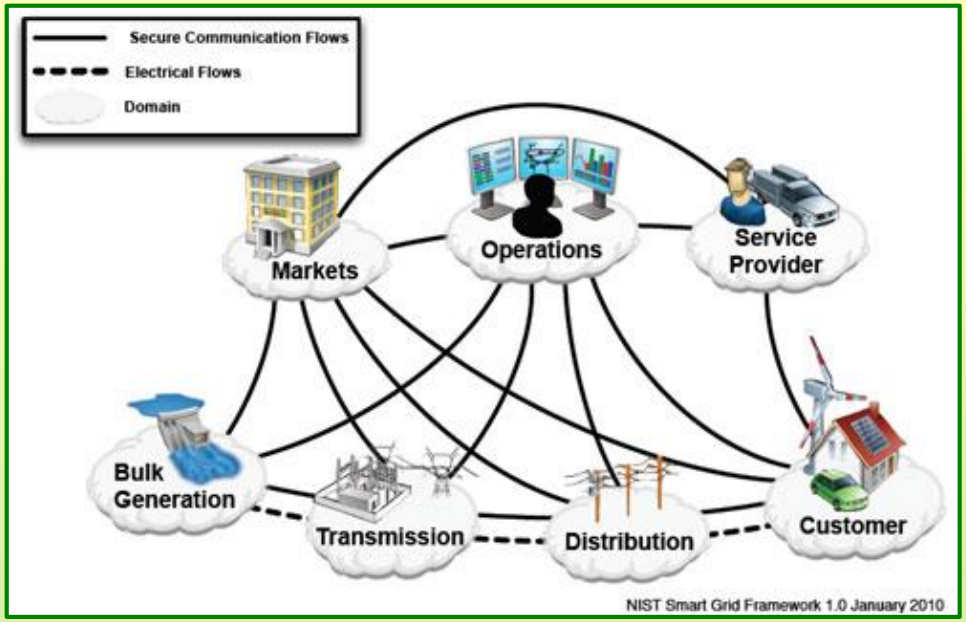
From a NIST Perspective

- The NIST Smart Grid Program aims to develop and deploy advances in measurement science to enable integration of interoperable and secure real-time sensing, control, communications, information and power technologies to increase efficiency, reliability and sustainability of the nation's electric grid.
- Promotes advances in cyber security and electrical metrology methodologies and standards for secure energy delivery



Smart Grid in the U.S.

From a NIST Perspective



- The NIST Smart Grid Program is a collaborative effort between U.S. industry and Government to establish advanced and secure energy delivery and generation
- U.S. Dept. of Energy leads the U. S. Government effort
- NIST has specific responsibilities for cyber security standards and for electrical metrology and standards

- Many new capabilities are becoming available to support smart grid systems
- Countries and regions that wish to enable distributed electricity generation, such as solar and wind-driven electrical, have the opportunity to take advantage of these capabilities as many are, or will be commercially available and comply with state-of-the-art electrical system characteristics.

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Muchas Gracias
Thank You

Questions or Discussion ?